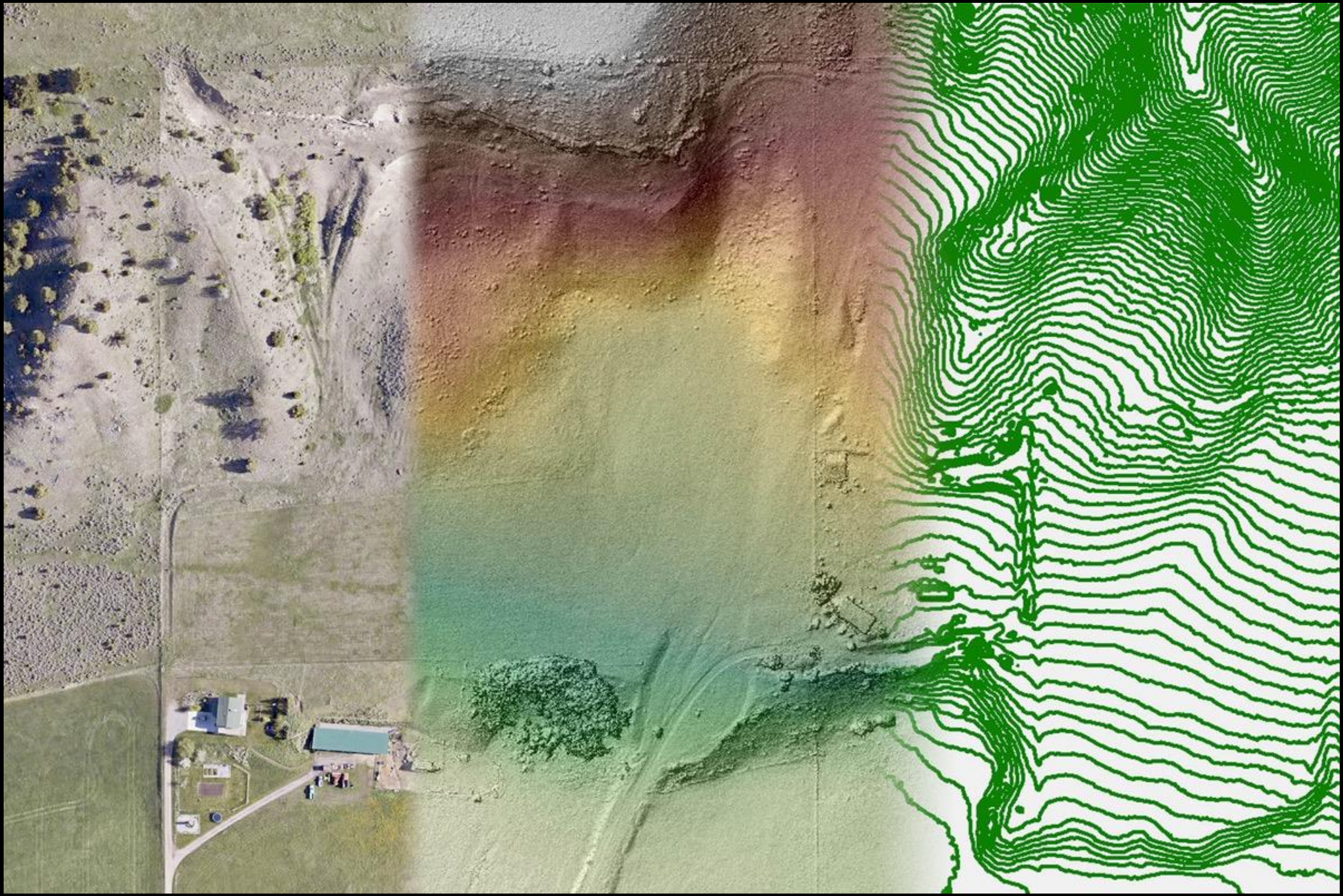
STRUCTURE FROM MOTION (SfM)
3D LANDSCAPE MAPPING AND MODELING:
A COST-EFFECTIVE ALTERANTIVE TO LIDAR



ASSOCIATION OF MONTANA FLOODPLAIN MANAGERS
17th ANNUAL CONFERENCE

CHRIS BOYER
CALEB LUCY

MARCH 17, 2016

Archaeology In The Ice Patches

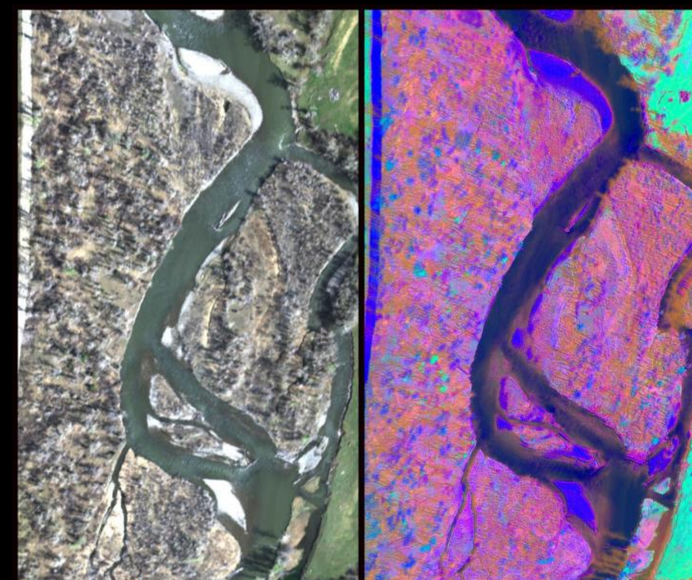
As Earth continues to warm, researchers rush to document and preserve archaeological remains exposed by melting ice patches.

By Tamara Stewart

In 2007, archaeologist Craig Lee recovered an incredibly-preserved, delicately-carved birch spear-throwing foreshaft from a melting ice patch north of Yellowstone National Park. The 10,300-year-old shaft, which Paleo-Indian people used to hunt big game, is the oldest artifact ever recovered from a North American ice patch. Lee, a research scientist at the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado and at Montana State University, is a practitioner of ice patch archaeology, an emerging field that identifies and recovers evidence of past human use of ancient alpine, arctic and sub-arctic environments being exposed

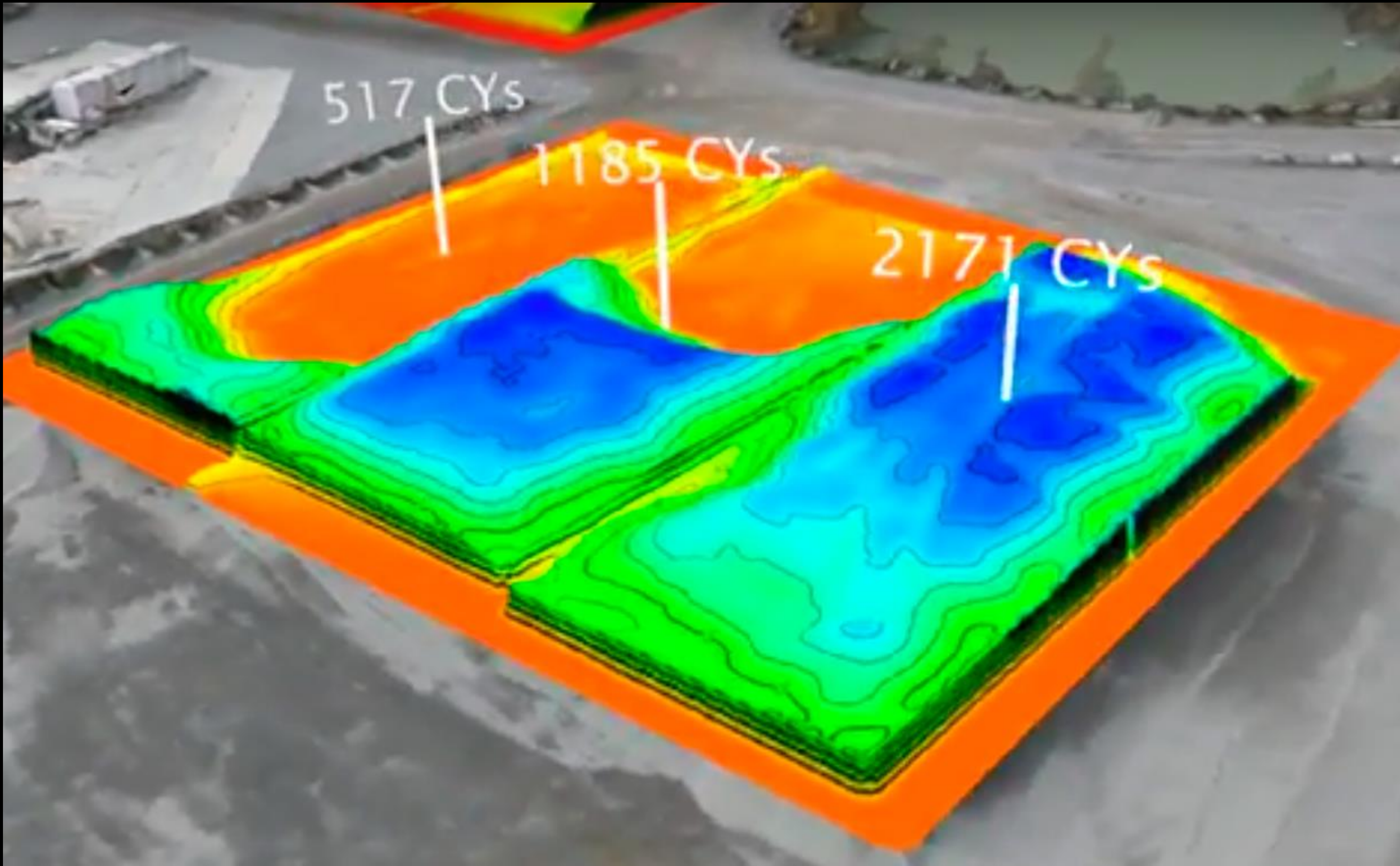
An aerial view of an ice patch located in the Greater Yellowstone Area. Aerial surveys help archaeologists determine which ice patches to focus on.

A 6,000-year-old digging stick emerges from a melting ice patch.

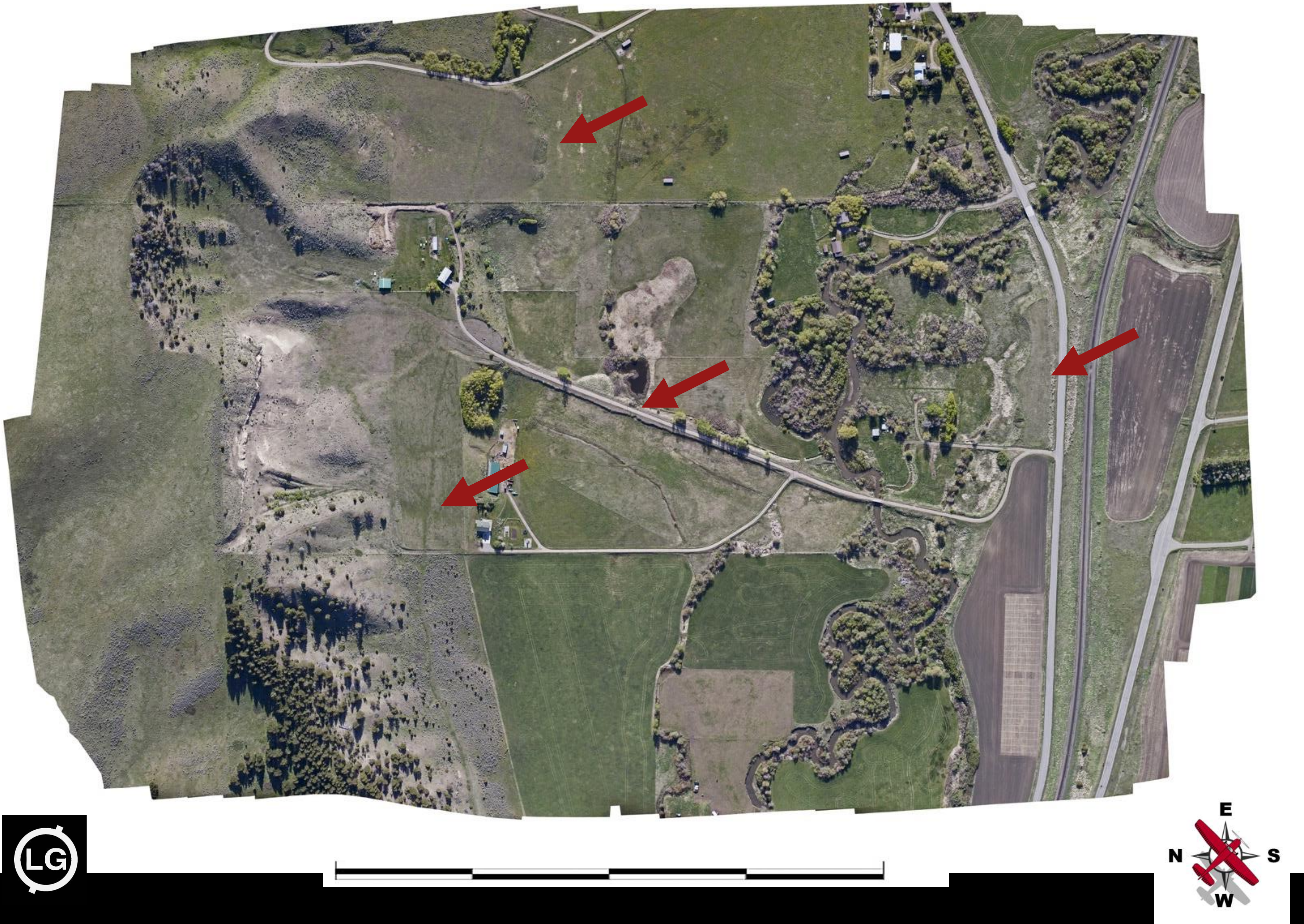


KESTREL AERIAL
LANDSCAPE DATA MADE VISIBLE

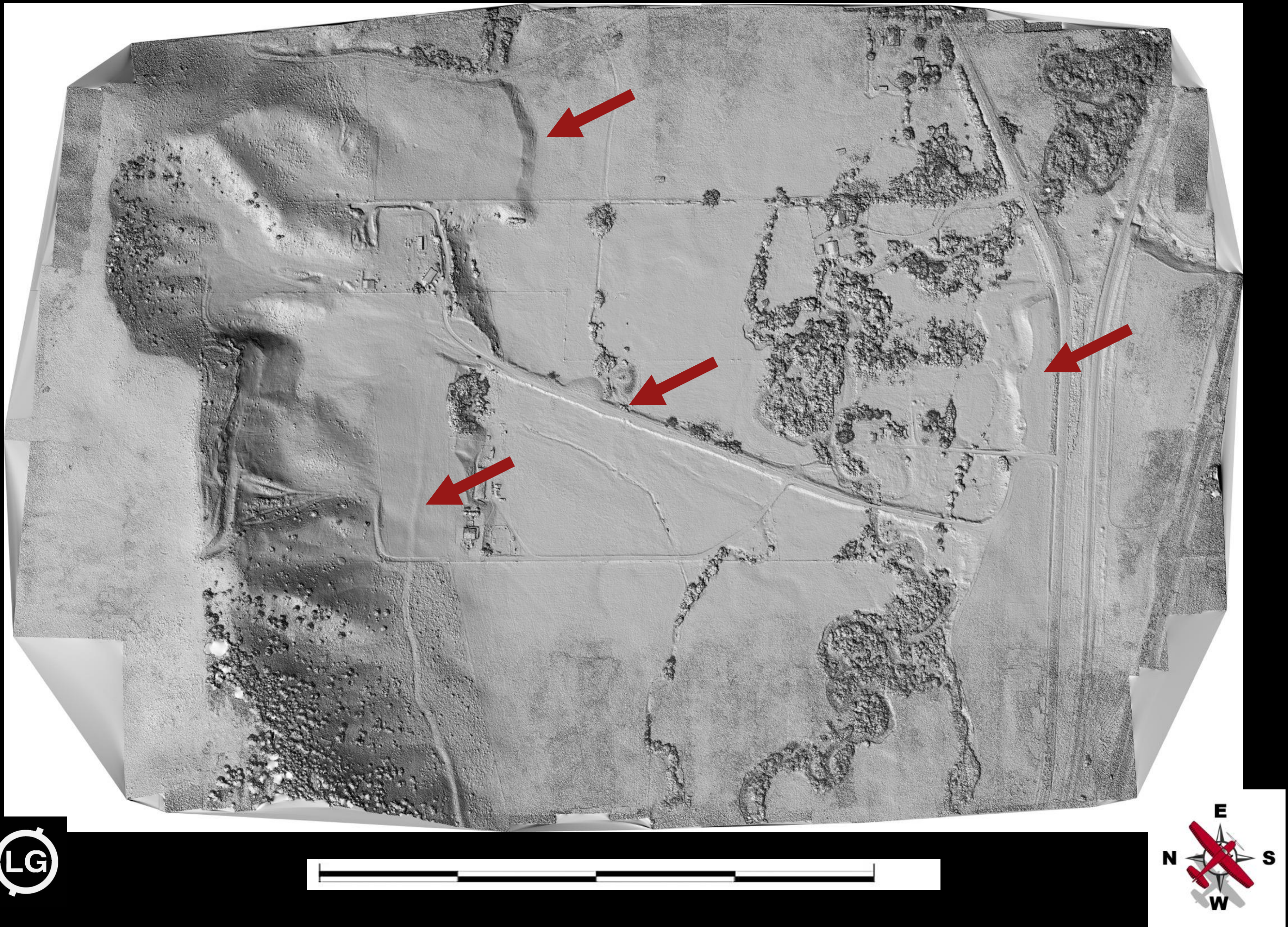
LG

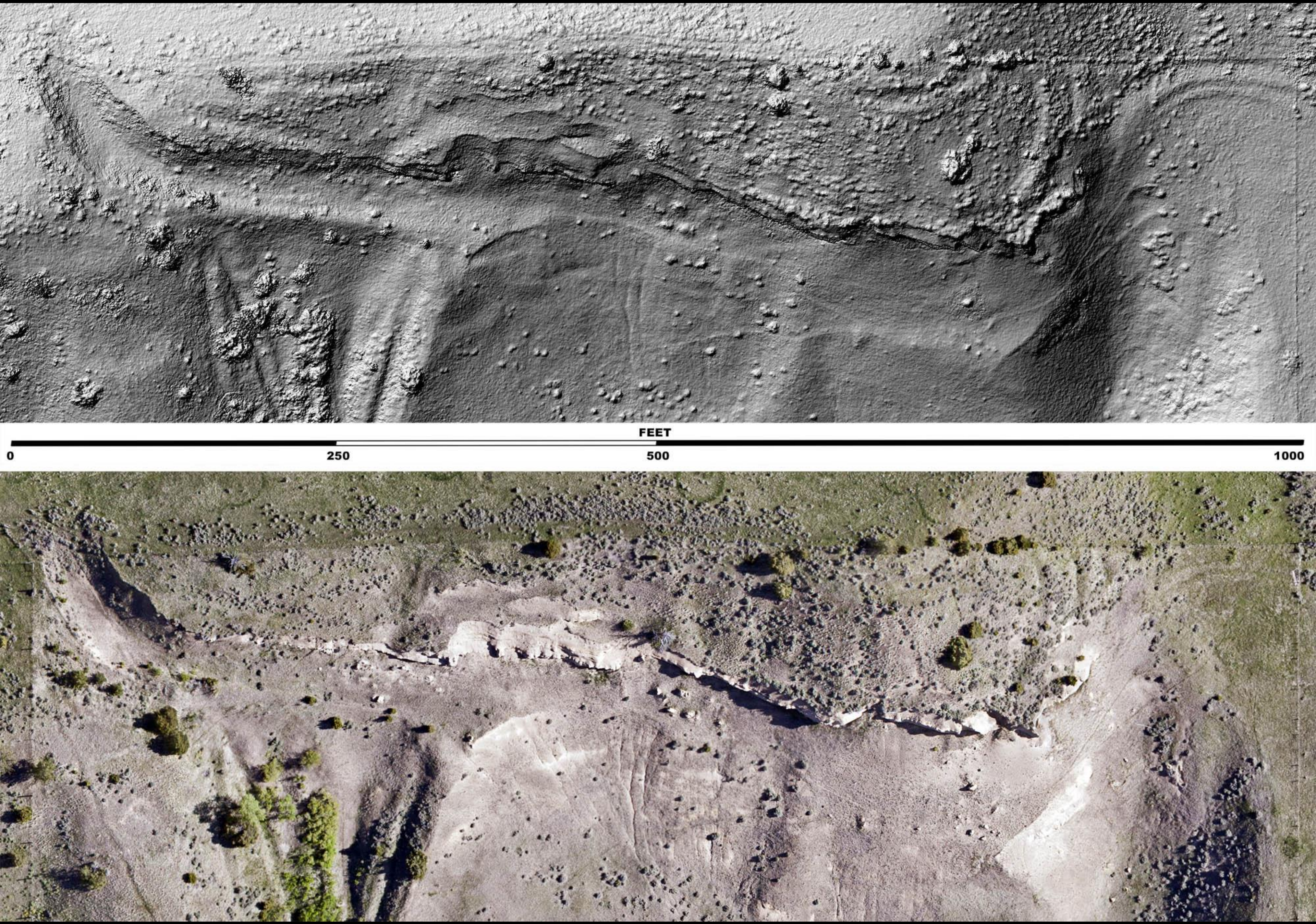


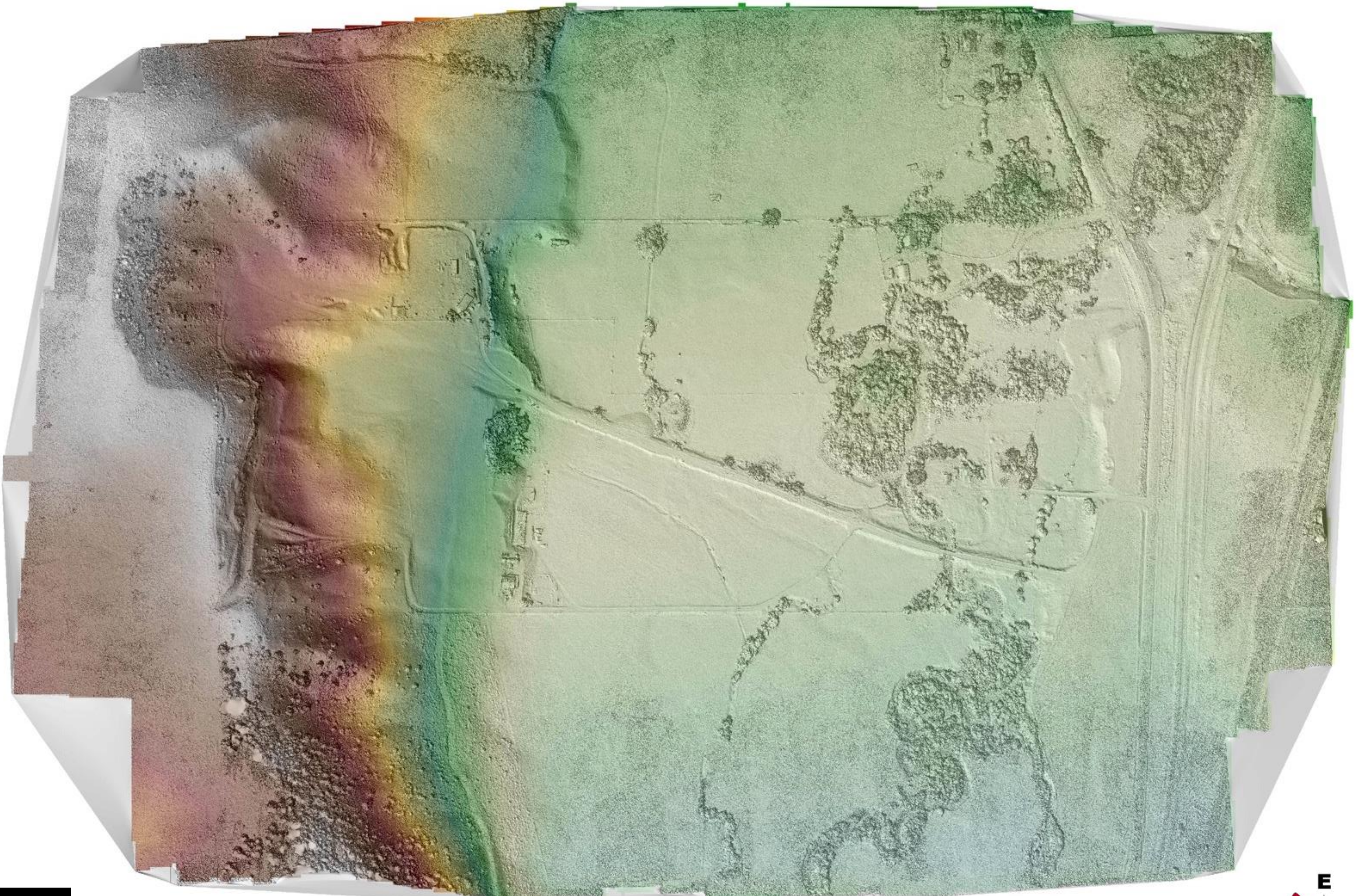
517 CYs
1185 CYs
2171 CYs



E
N
S
W


E
N
S
W


FEET
0
250
500
1000




E
N
S
W

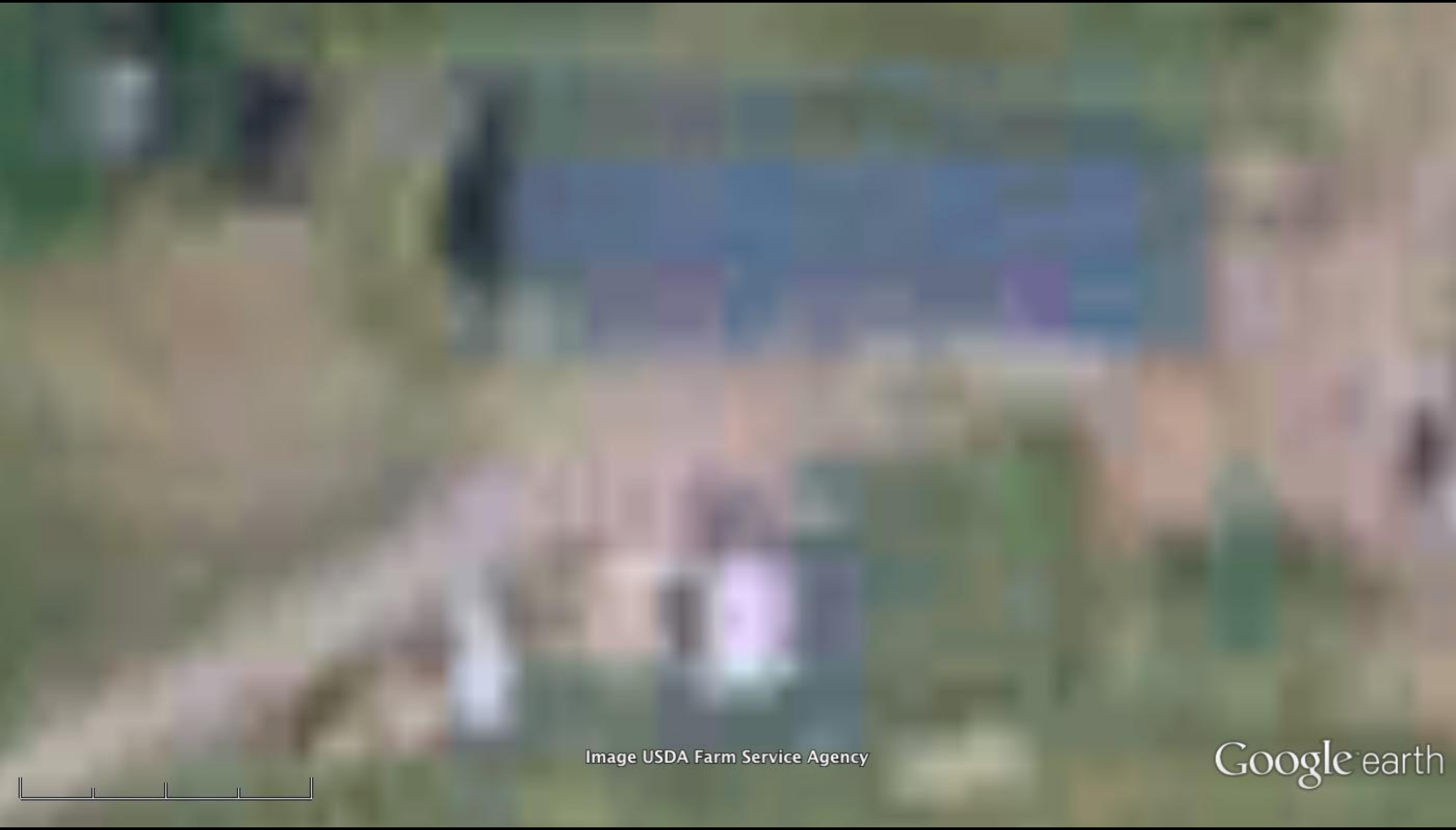
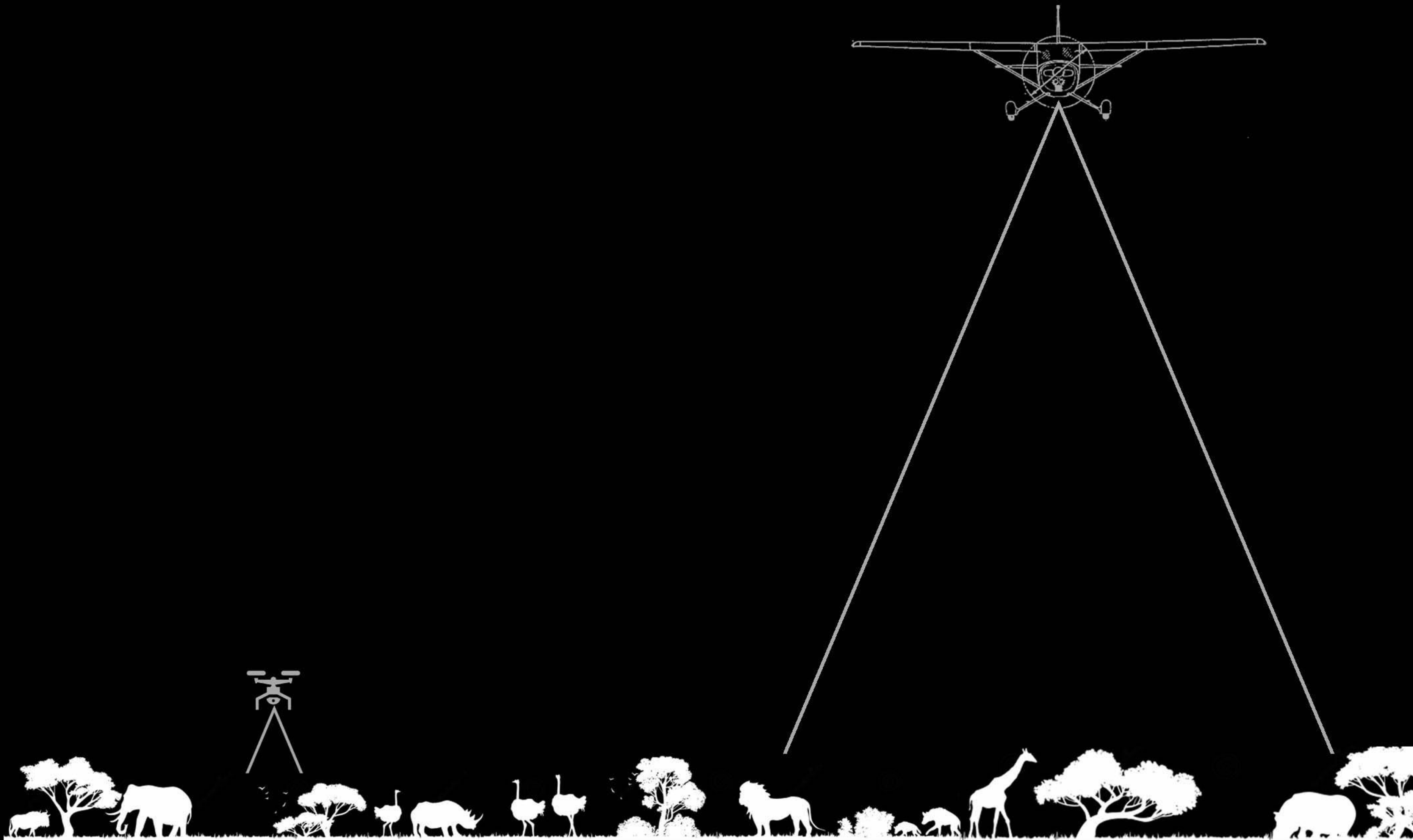
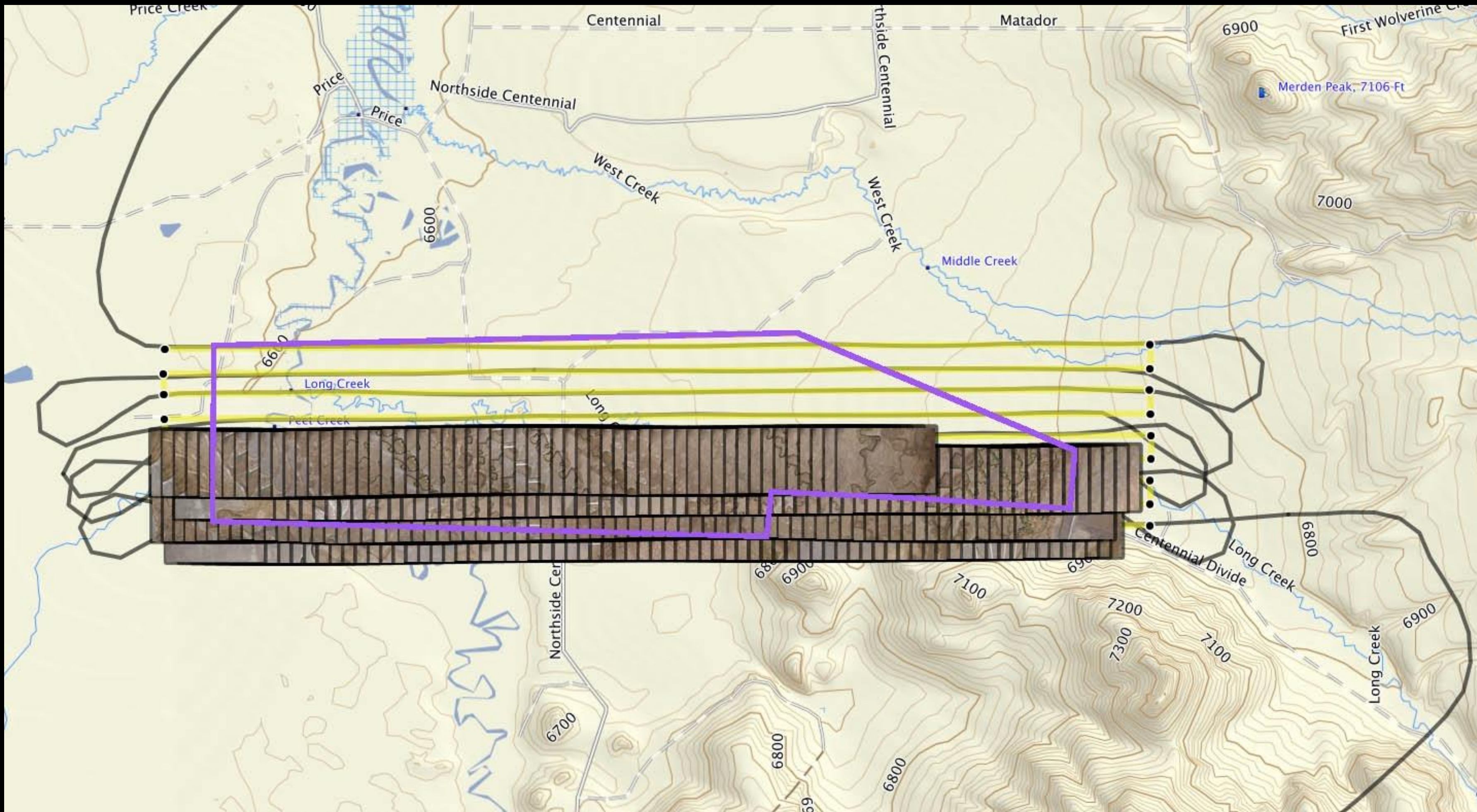


Image USDA Farm Service Agency
Google earth

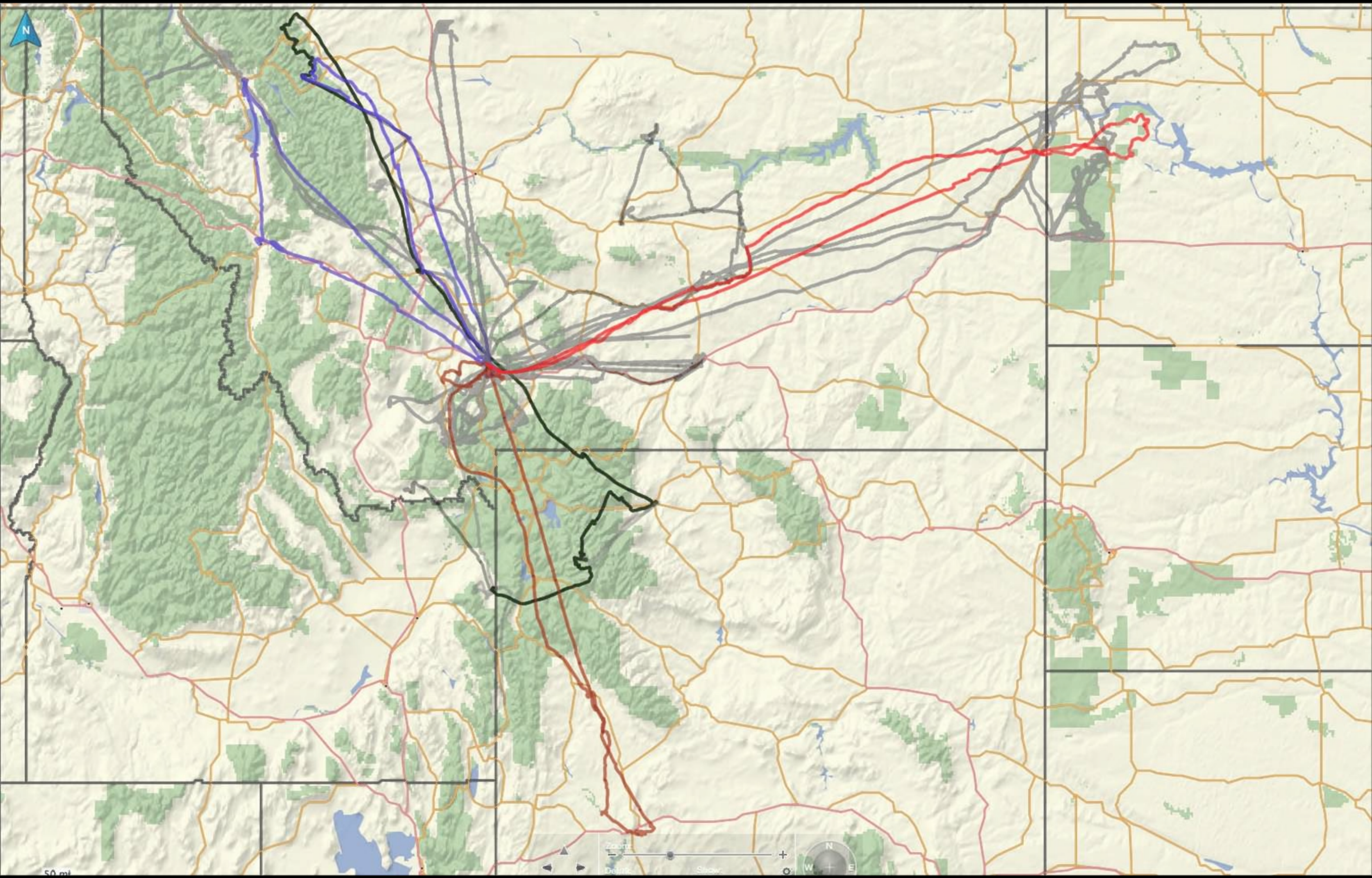


50MM LENS
400’ AGL
288’ x 192’ COVERAGE
1.25 ACRES

50MM LENS
2,500’ AGL
1,800’ x 1,200’ COVERAGE
50 ACRES



Centennial
Matador
Northside Centennial
Price
Price
West Creek
West Creek
Middle Creek
Merden Peak, 7106 Ft
First Wolverine
6900
7000
6600
6600
Long Creek
Peet Creek
Northside Cen
Centennial Divide
Long Creek
Long Creek
7100
7200
7300
7100
6900
6900
6700
6800
6800


N
50 mi

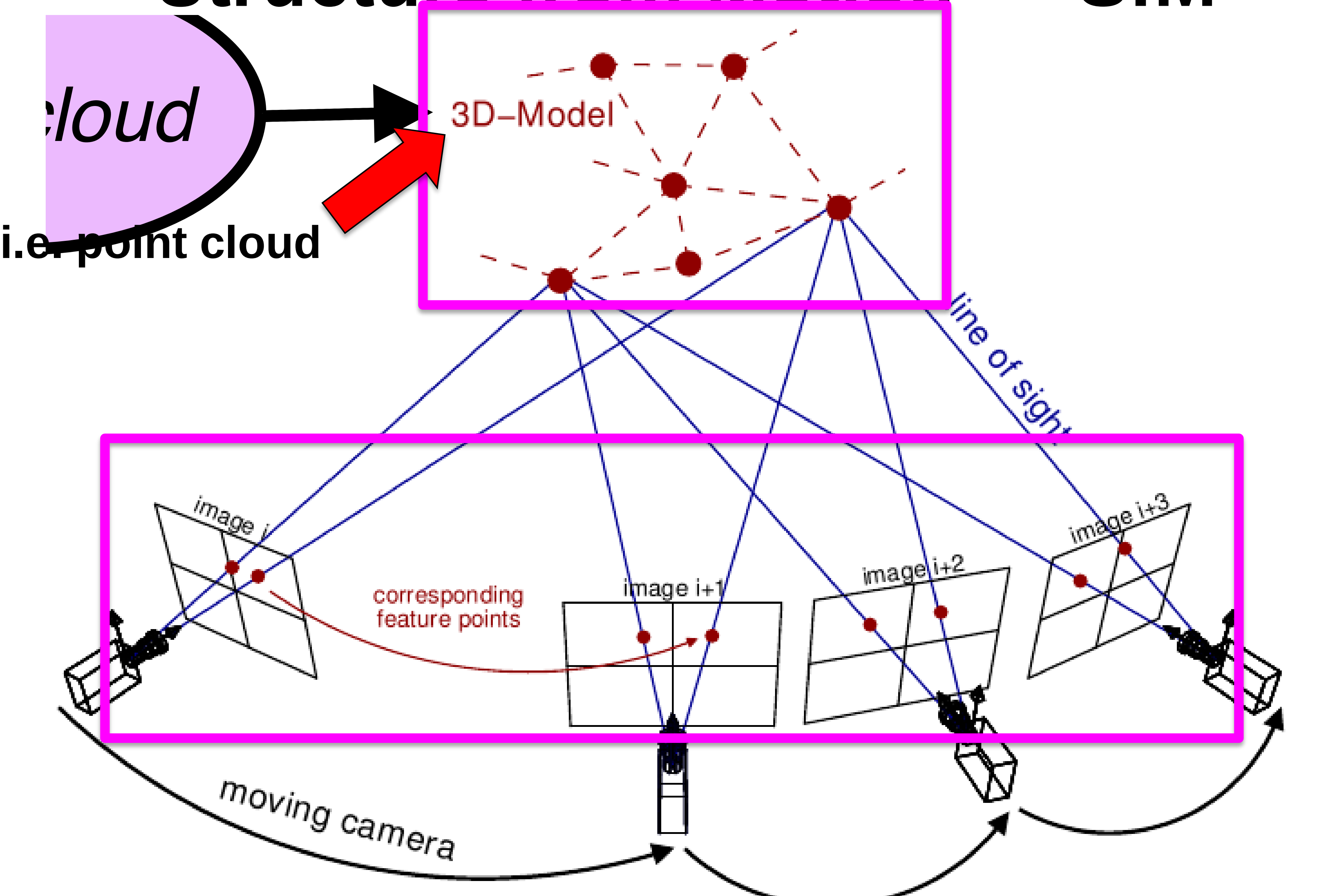
STRUCTURE FROM MOTION (SfM) 3D LANDSCAPE MAPPING AND MODELING: A COST-EFFECTIVE ALTERNATIVE TO LIDAR

ASSOCIATION OF MONTANA FLOODPLAIN MANAGERS
17th ANNUAL CONFERENCE

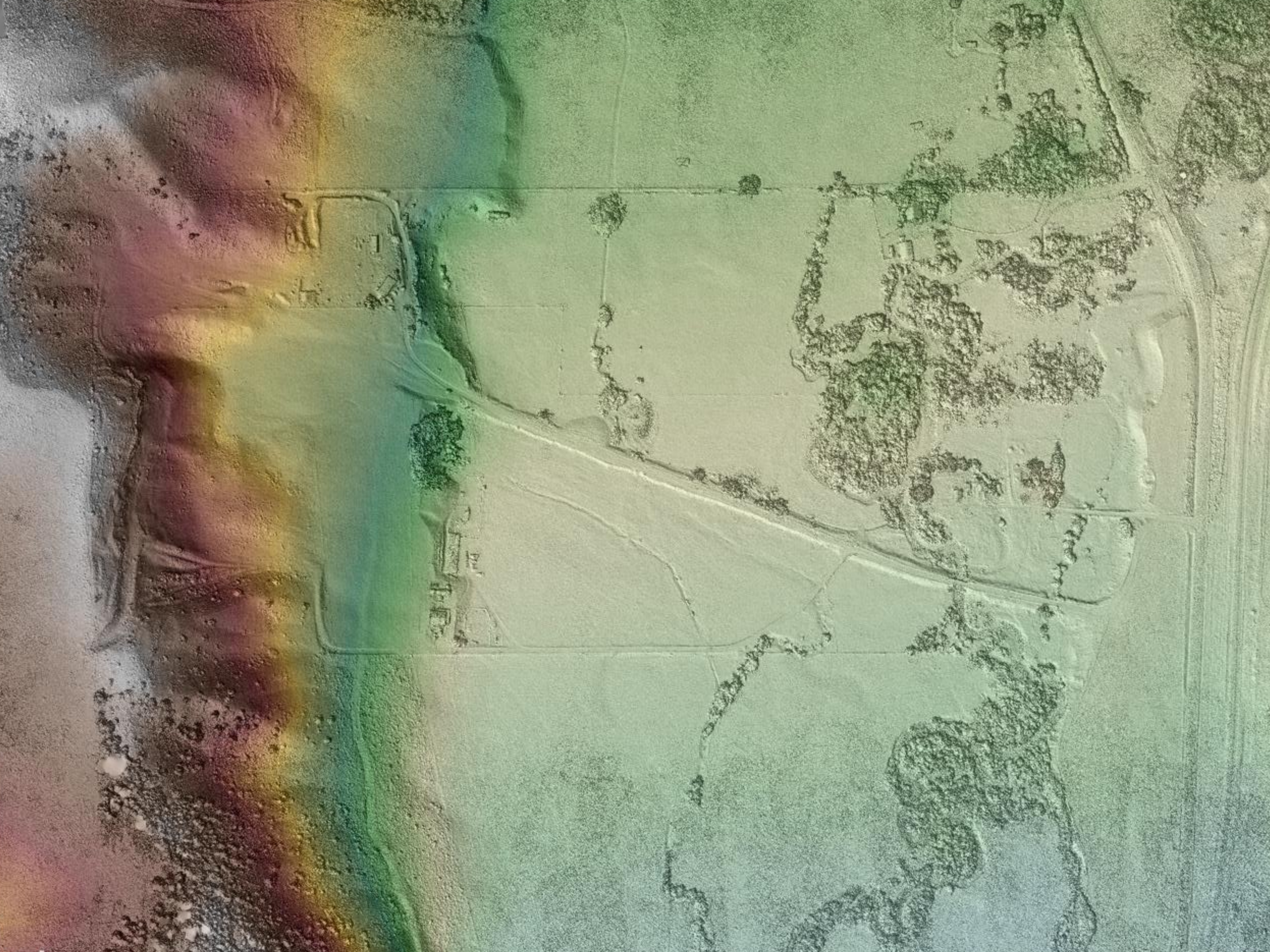
CHRIS BOYER
CALEB LUCY

MARCH 17, 2016

"Structure from Motion" – SfM



(Ackermann et al. 2013)

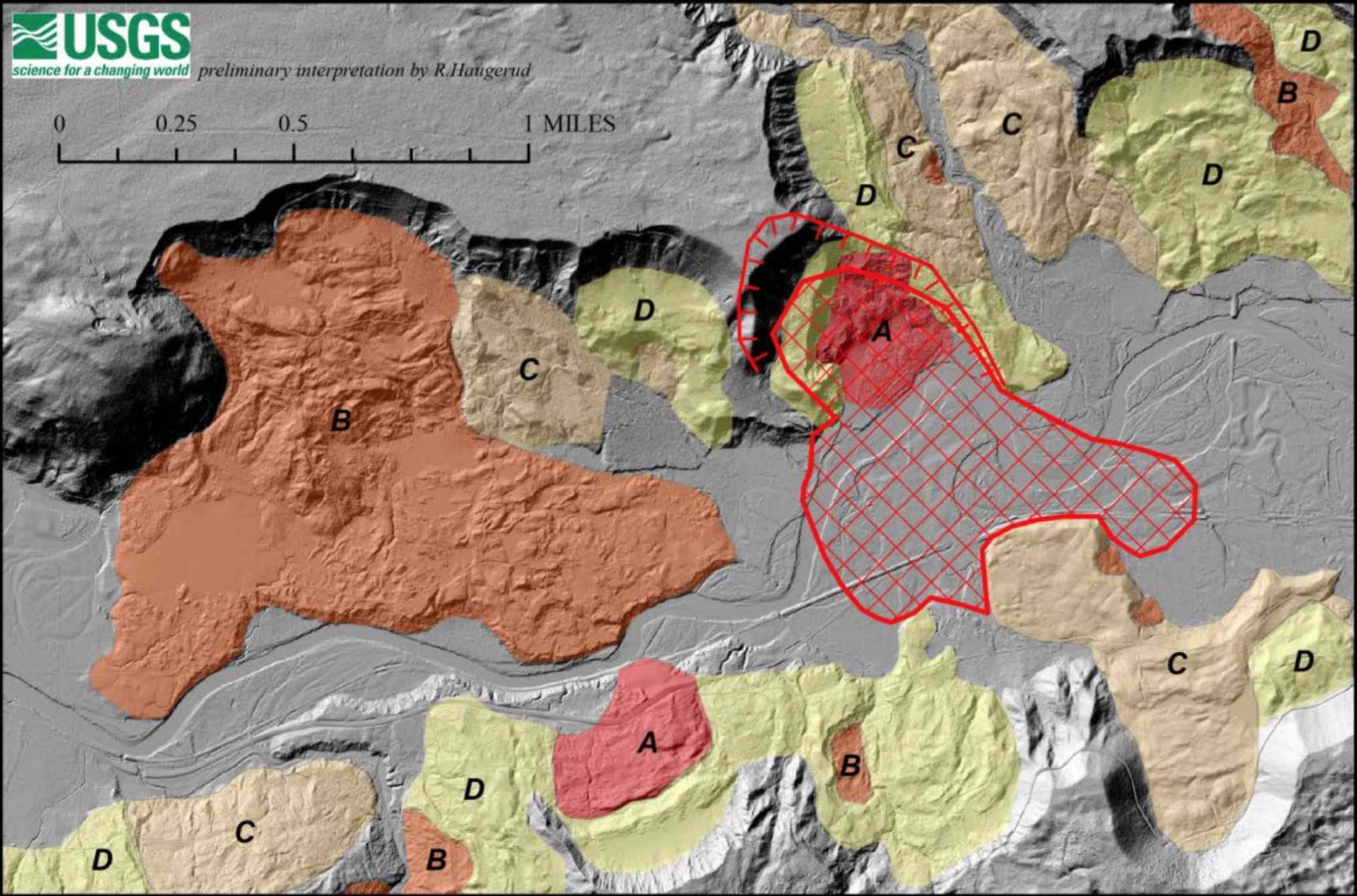


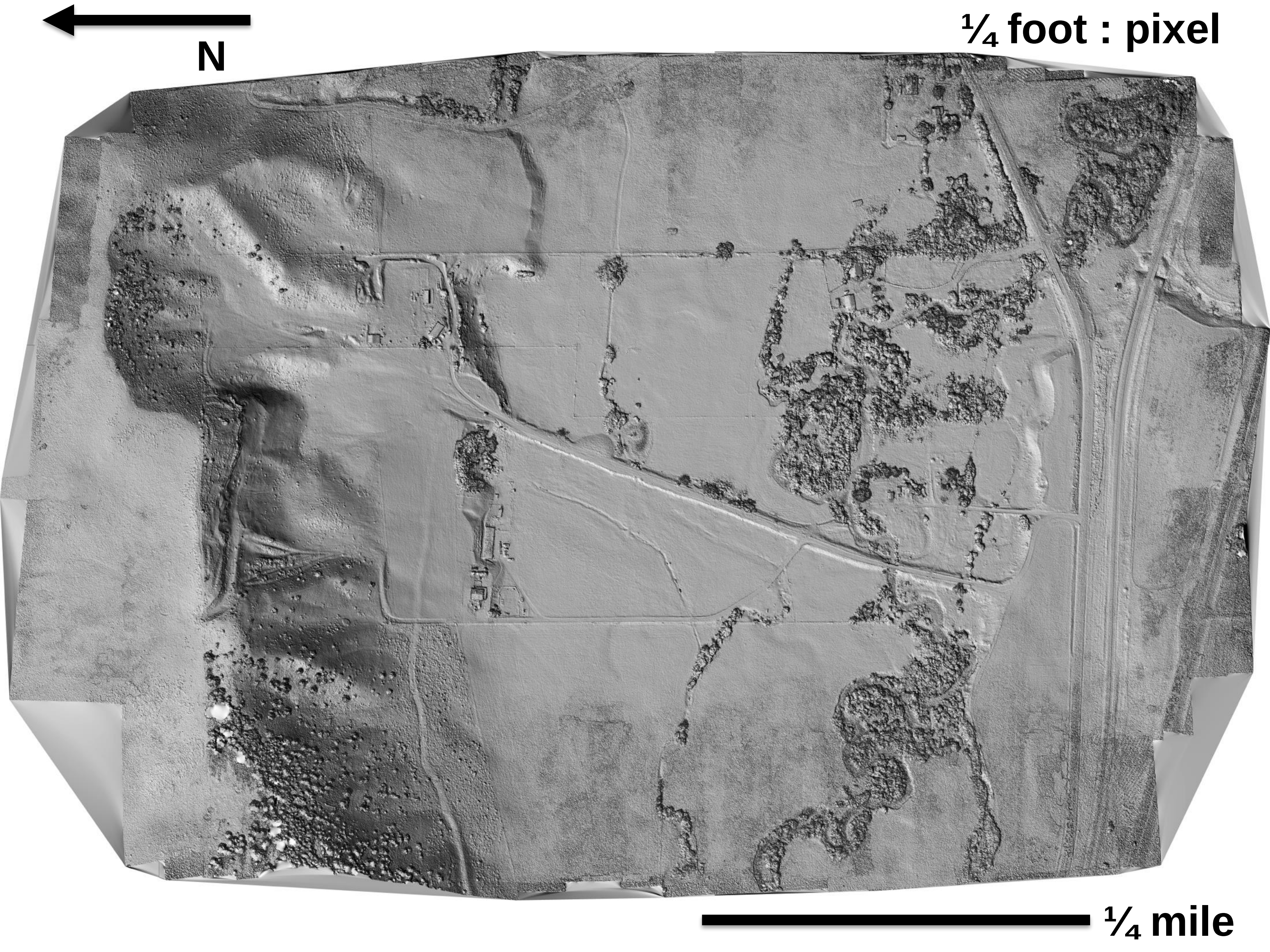
3/22/2014: Landslide in Oso, WA

"How to Make Landslides Less Deadly"
by David R. Montgomery and Joseph Wartman
NYT 3/20/2015

Over the past decade, the science of landslide mapping has advanced rapidly, largely because of improvements in remote sensing technologies that allow us to see Earth's surface in unprecedented detail. Today, it would be possible to create high-resolution hazard maps for the entire nation for significantly less than the estimated $1 billion or more in losses that landslides cause each year in the United States.

These high-resolution maps are available in other countries, including New Zealand, Italy and Switzerland, where they provide valuable information to citizens and public officials about risks. They guide land-use policy and allow people to make informed decisions before buying or building a home.


USGS
science for a changing world
preliminary interpretation by R.Haugerud
0
0.25
0.5
1 MILES
A
B
C
D
(USGS)


N
¼ foot : pixel
¼ mile

ELSEVIER

Geomorphology

Volume 200, 15 October 2013, Pages 172–183

The Field Tradition in Geomorphology 43rd Annual Binghamton Geomorphology Symposium, held 21-23 September 2012 in Jackson, Wyoming USA

‘You are HERE’: Connecting the dots with airborne lidar for geomorphic fieldwork

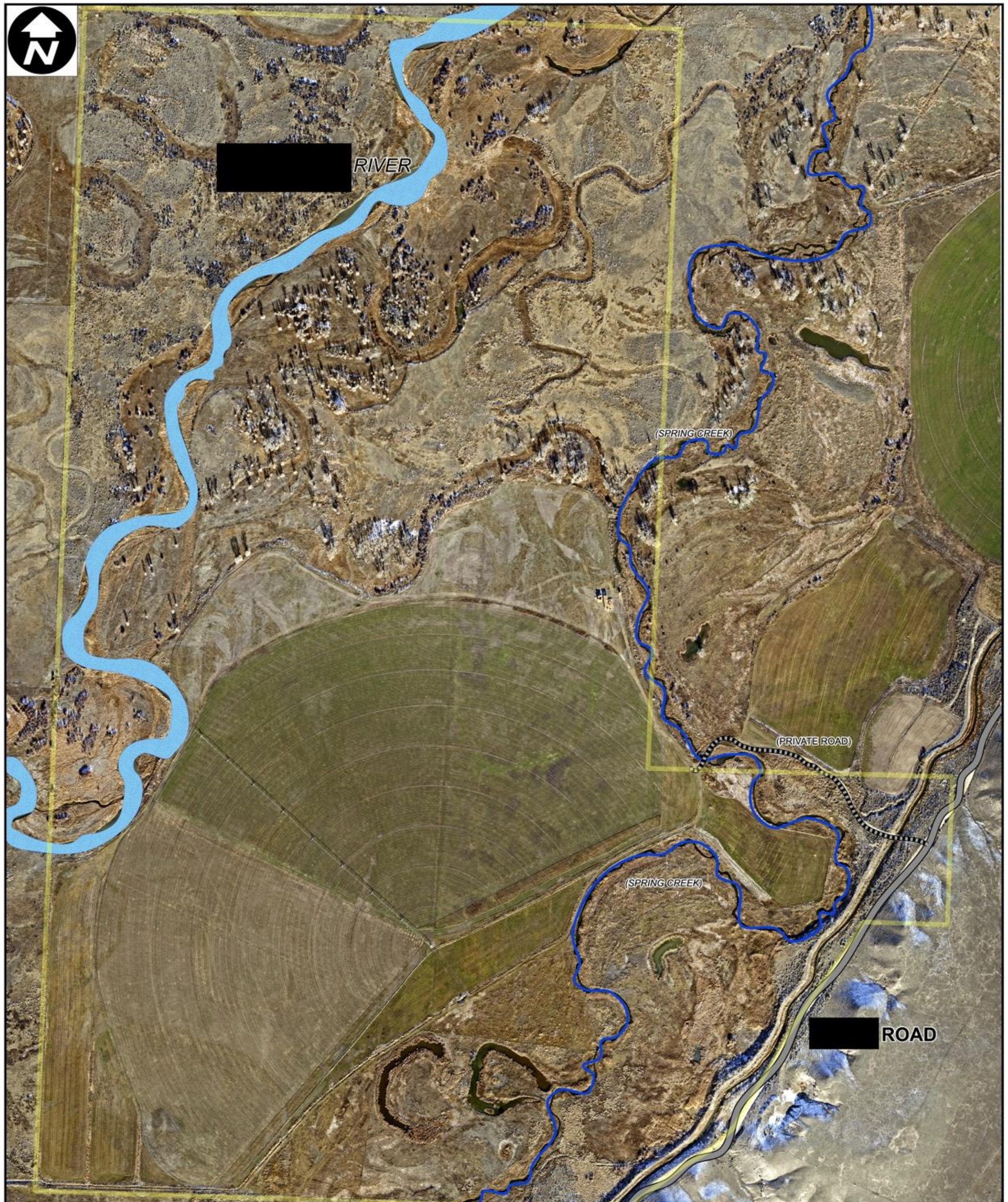
Joshua J. Roering, Benjamin H. Mackey[1], Jill A. Marshall, Kristin E. Sweeney, Natalia I. Deligne[2], Adam M. Booth[3], Alexander L. Handwerger, Corina Cerovski-Darriau

Show more

Lidar (and high-resolution landscape imagery in general) affords:

1) **Best basemap, esp. for guiding field studies***
2) **More information to evaluate, more robust results**
3) **Perspective to identify previously unknown landscape features**

*** = one to one pixel correspondence gives SfM a distinct edge here**



[redacted] PROPERTY BOUNDARY

PRIVATE ROAD

PUBLIC ROAD

MAIN STEM RIVER CHANNEL

TRIBUTARY

[redacted]

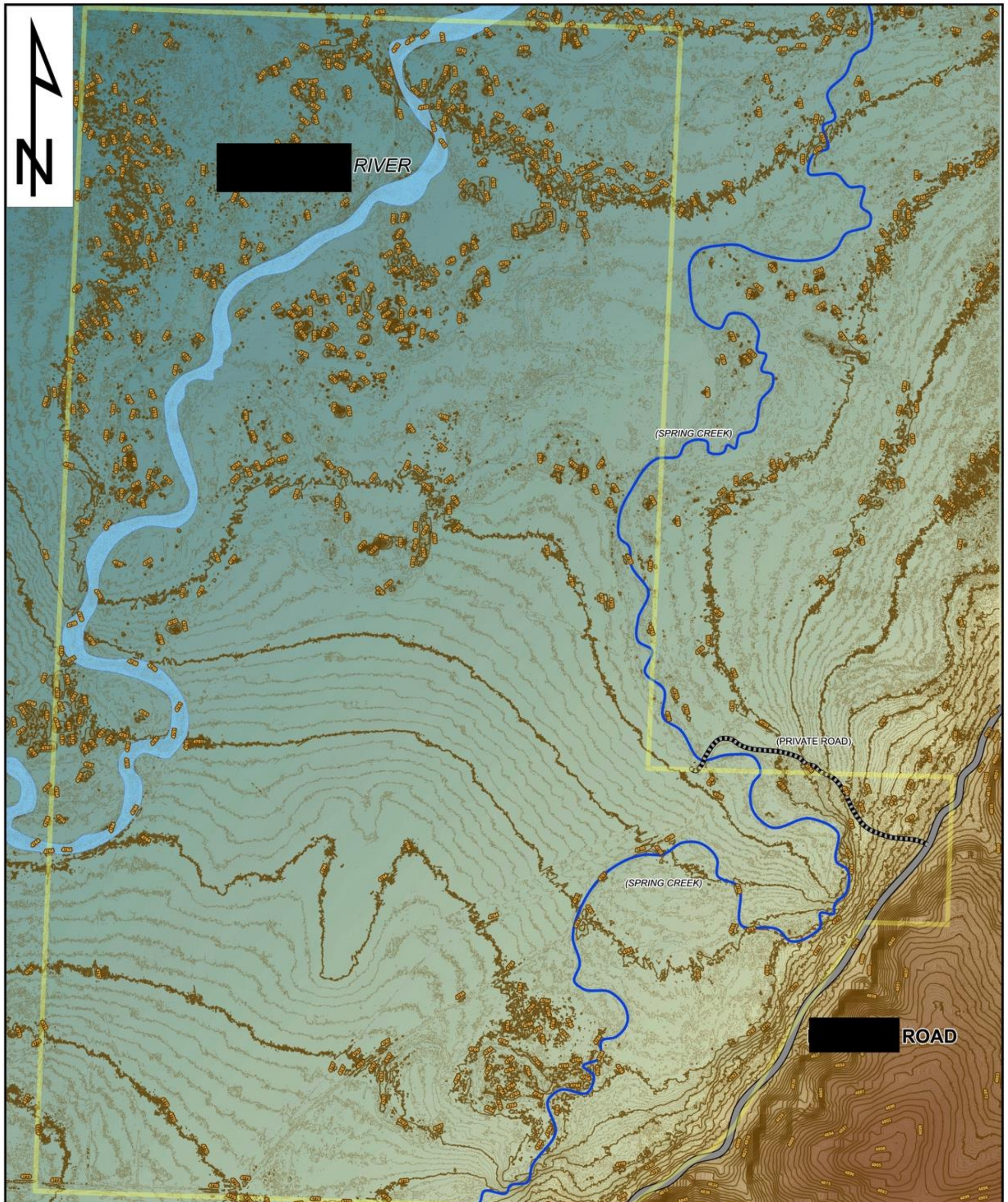
0 0.1 0.2 0.4

Miles

RESOLUTION: 0.25 FEET / PIXEL
HORIZONTAL: MT STATE PLANE / NAD83 (FEET)
VERTICAL: NAVD88 (FEET)

[redacted]

IMAGERY: KESTRELAERIAL.COM
MAPPING: LUCYGEOSPATIAL.COM



[redacted] PROPERTY BOUNDARY

ELEVATION (FEET)
4850
4750

PRIVATE ROAD
PUBLIC ROAD
MAIN STEM RIVER CHANNEL
TRIBUTARY
0.5 FOOT CONTOUR
3 FOOT CONTOUR

[redacted]

0 0.1 0.2 0.4
Miles

RESOLUTION: 0.25 FEET / PIXEL
HORIZONTAL: MT STATE PLANE / NAD83 (FEET)
VERTICAL: NAVD88 (FEET)

[redacted]

IMAGERY: KESTRELAERIAL.COM
MAPPING: LUCYGEOSPATIAL.COM

"Point Clouds: Lidar versus 3D Vision"

from F. Leberl et al (2010) *Photogrammetric Engineering & Remote Sensing*

TABLE 3. SIXTEEN ADVANTAGES OF THE PHOTOGRAMMETRIC 3D WORKFLOW OVER THE DIRECTLY MEASURED LASER POINT CLOUDS

Accuracy and Errors

1. Large area rigid camera image block geometry via AT at a sub-pixel accuracy
2. Error checking using redundant observations as a system-inherent verification
3. Internal accuracy measures from redundancy
4. Geometric accuracy by AT superior to a reliance on GPS/IMU to fuse patches into seamless coverage
5. Greater point density → for better defined discontinuities

Economy

6. Superior data collection efficiency with faster vehicles, larger swaths
7. Single workflow within aerial application, all image-based
8. Single workflow across widely varying applications (aerial, street-side & indoor)
9. No occlusions using no-cost along-track high image overlaps

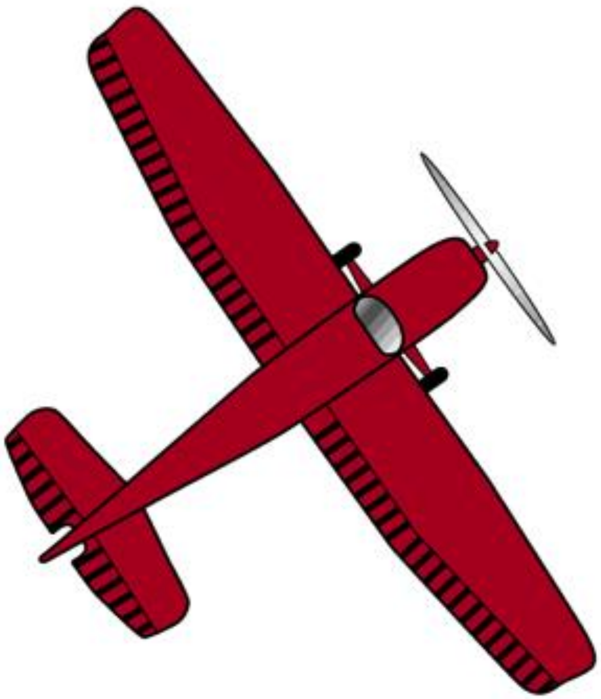
Data Types

10. 2D-image information augmenting 3D data points
11. Multi-spectral image classification
12. Urban façade textures available at no cost from the air at image edges
13. Images document details → example street signs can be read automatically

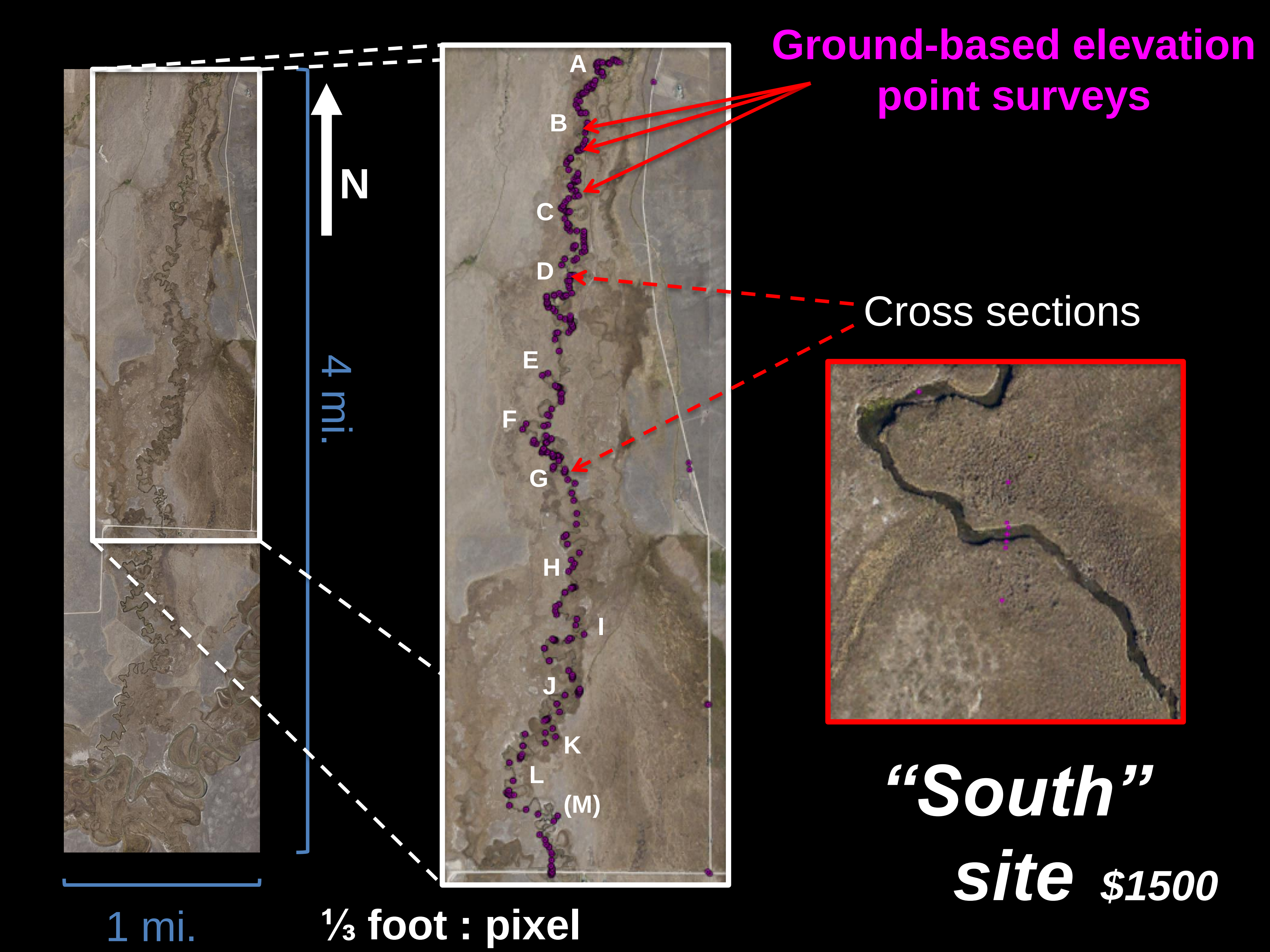
Miscellaneous

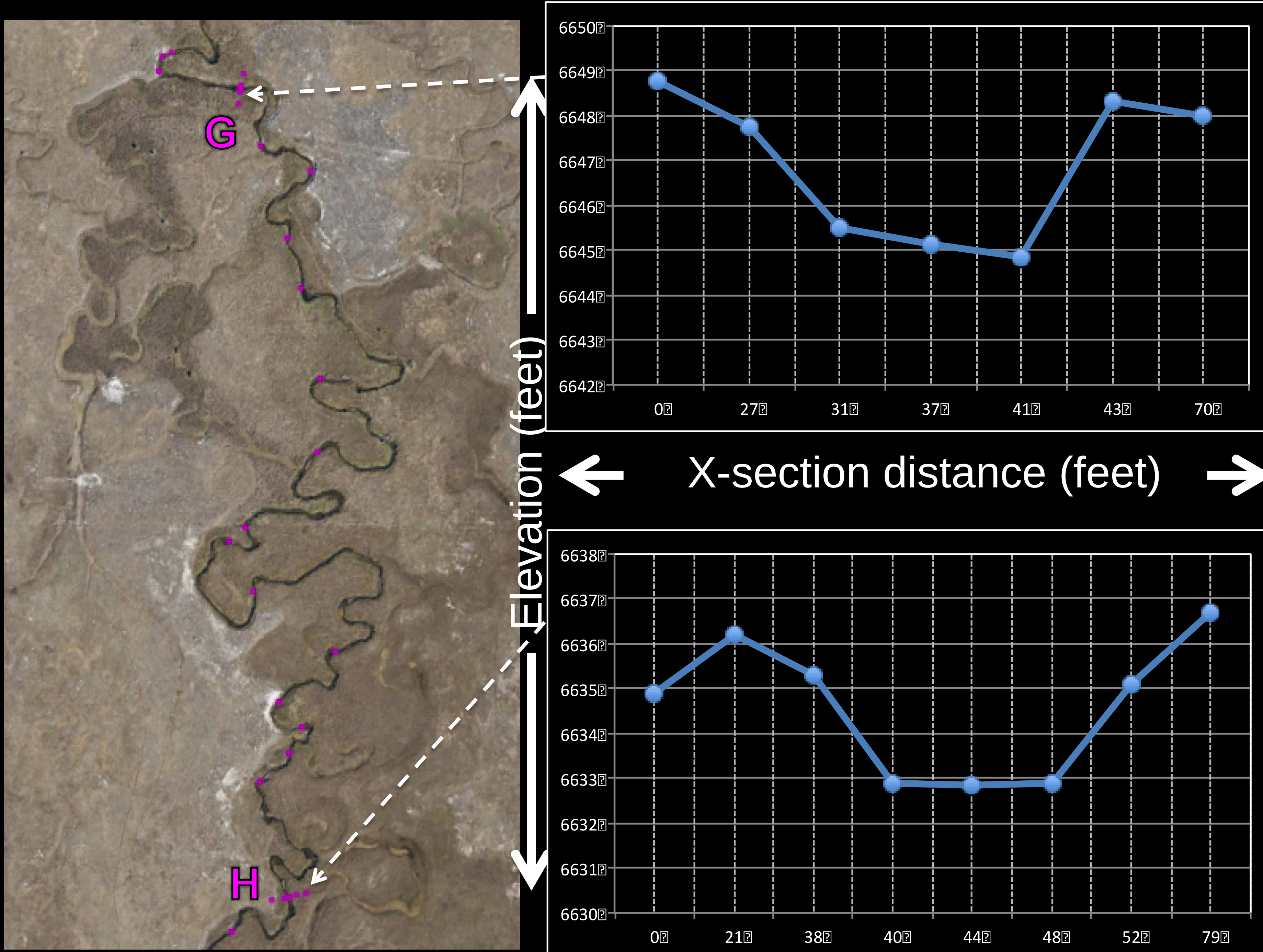
14. *Perspective exists towards Real time 3DVision* via "*supercomputer in match box*"
15. Full automation needs image redundancy → lidar adds little to automation
16. Scene interpretation is becoming important and needs imagery → lidar adds little

Objective



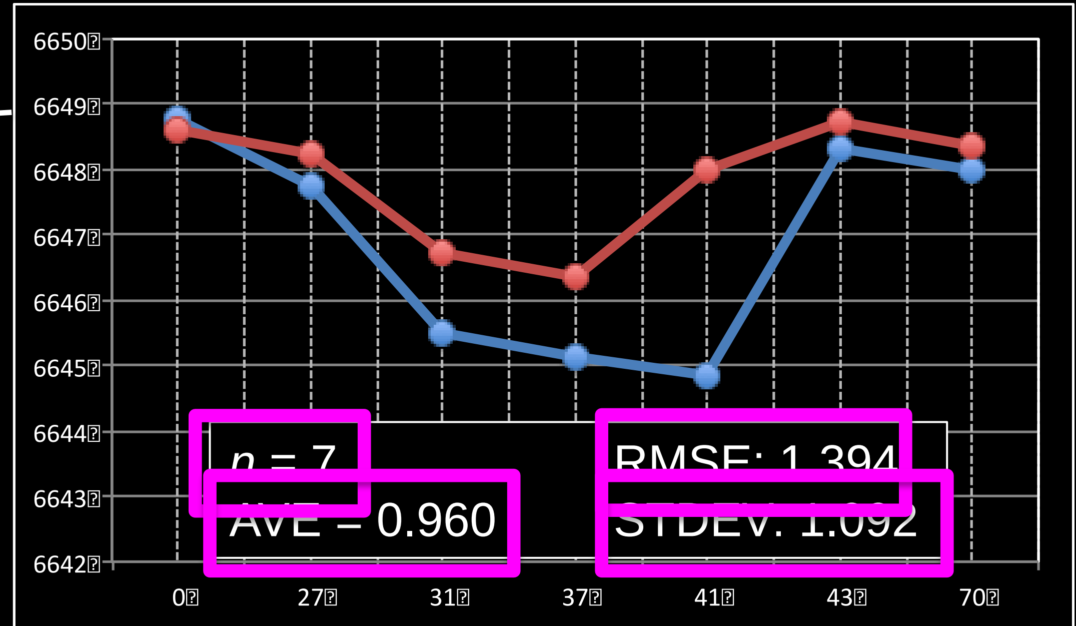
v.

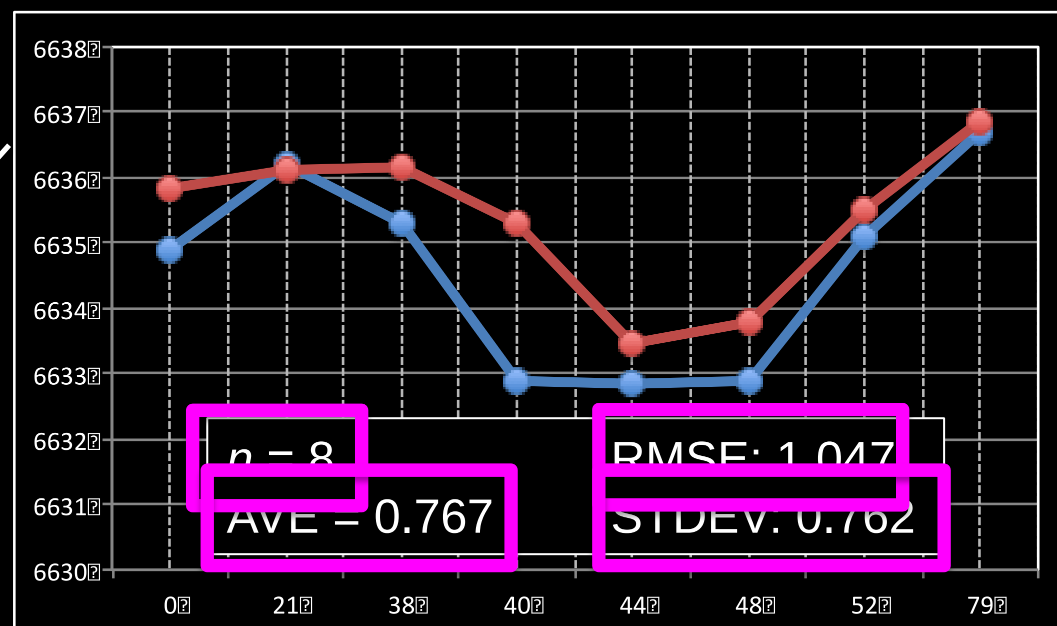

Ground-based elevation point surveys
N
4 mi.
A
B
C
D
E
F
G
H
I
J
K
L
(M)
Cross sections
"South" site $1500
1 mi.
⅓ foot : pixel



G
H
Elevation (feet)
X-section distance (feet)
6650
6649
6648
6647
6646
6645
6644
6643
6642
0
27
31
37
41
43
70
6638
6637
6636
6635
6634
6633
6632
6631
6630
0
21
38
40
44
48
52
79


G
H


6650
6649
6648
6647
6646
6645
6644
6643
6642
0
27
31
37
41
43
70
n = 7
RMSE: 1.394
AVE = 0.960
STDEV: 1.092


6638
6637
6636
6635
6634
6633
6632
6631
6630
0
21
38
40
44
48
52
79
n = 8
RMSE: 1.047
AVE = 0.767
STDEV: 0.762

“SOUTH” SITE-WIDE
z(SfM)-z(LS)
RESULTS SUMMARY

0.718 ft ±1.689 (1.833 RMSE; n = 565) — *raw*

0.378 ft ±1.563 (1.606 RMSE; n = 341) — *subaerial*

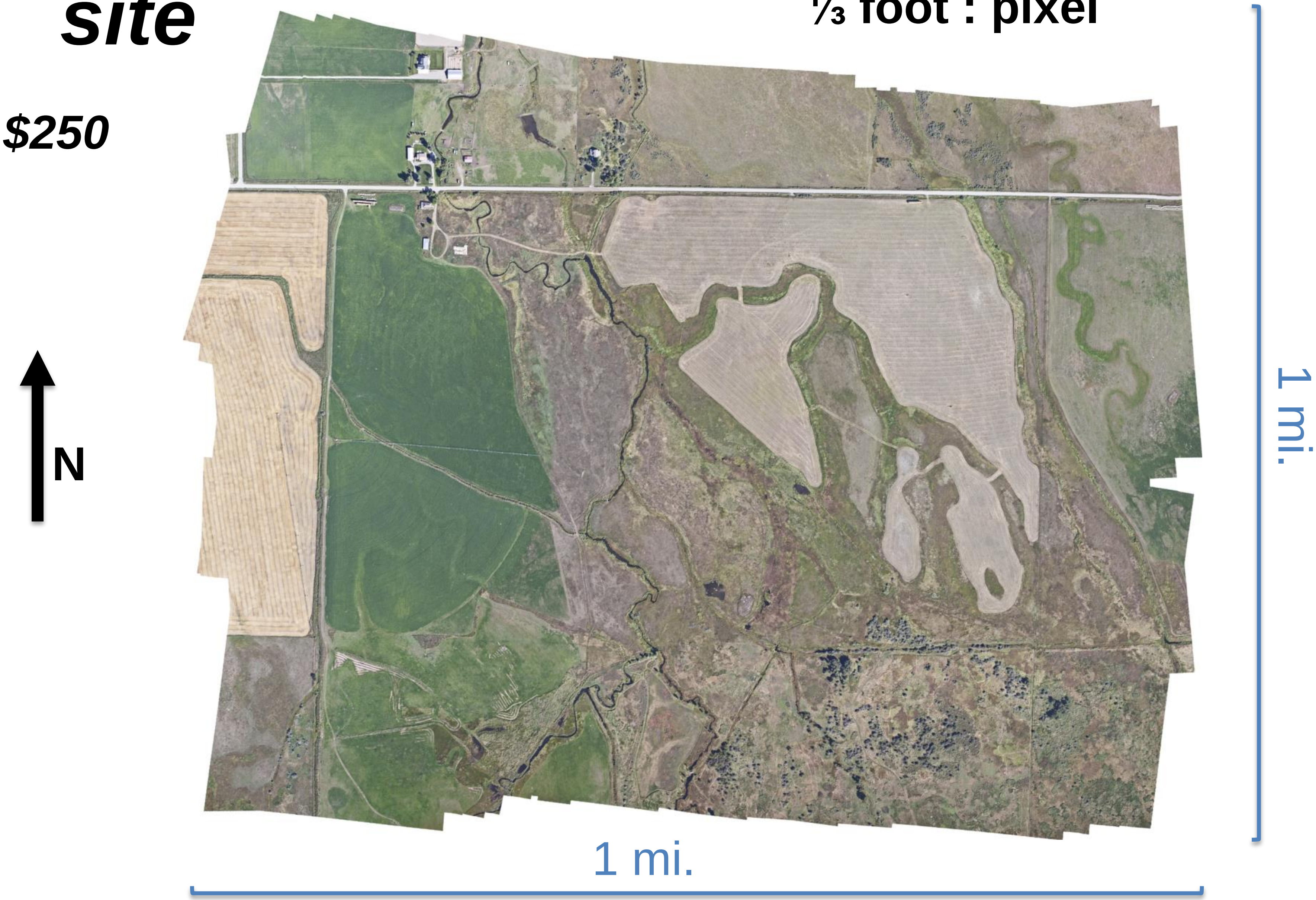
1.236 ft ±1.743 (2.133 RMSE; n = 224) — *subaqueous*

(13) cross sections: 0.813 ft ±1.359 (1.578 RMSE; n = 104)

"North" site

$250

⅓ foot : pixel



“NORTH” SITE-WIDE
z(SfM)-z(LS)
RESULTS SUMMARY

0.007 ft ±1.700 (3.213 RMSE; n = 691) — *raw*

-0.077 ft ±1.730 (3.158 RMSE; n = 616) — *subaerial*

0.693 ft ±1.250 (3.631 RMSE; n = 75) — *subaqueous*

(29) cross sections: -0.225 ft ±1.464 (1.476 RMSE; n = 301)

Conclusions / Future work

- Further model testing

- Image classification

- Repeat surveys

... ???

ACKNOWLEDGEMENTS

Chris Boyer
Scott Gillian @ Gaia Resources
Noah Snyder @ Boston College